

# The Future of Hard QGP Probes at RHIC: sPHENIX



Gunther Roland (MIT)  
for the sPHENIX collaboration



## REACHING FOR THE HORIZON

The Site of the Wright Brothers' First Airplane Flight

### The 2015 LONG RANGE PLAN for NUCLEAR SCIENCE



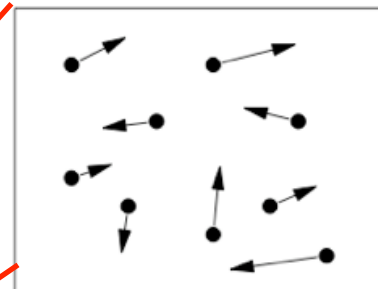
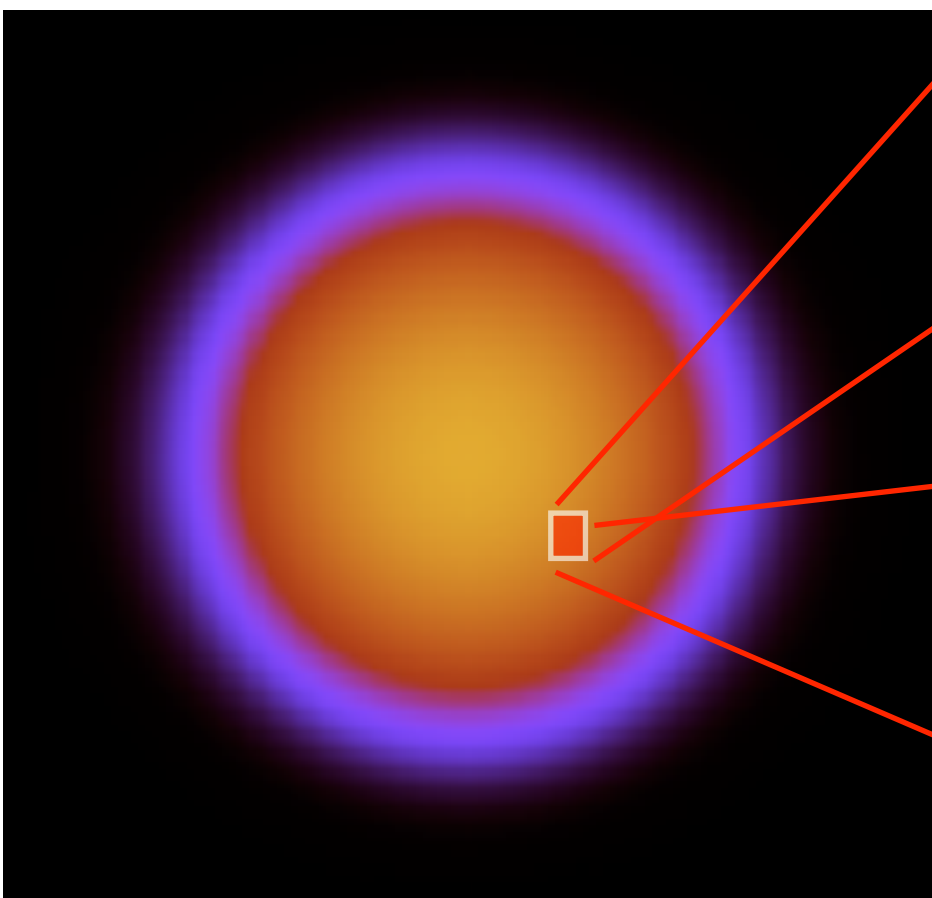
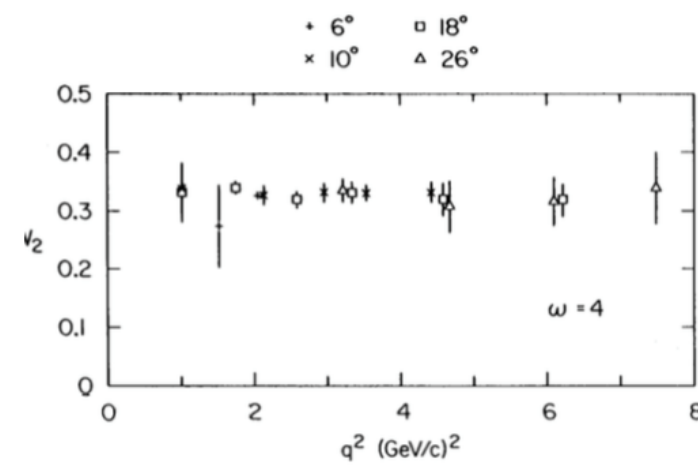
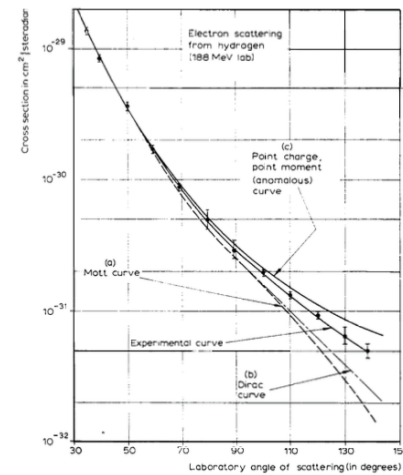
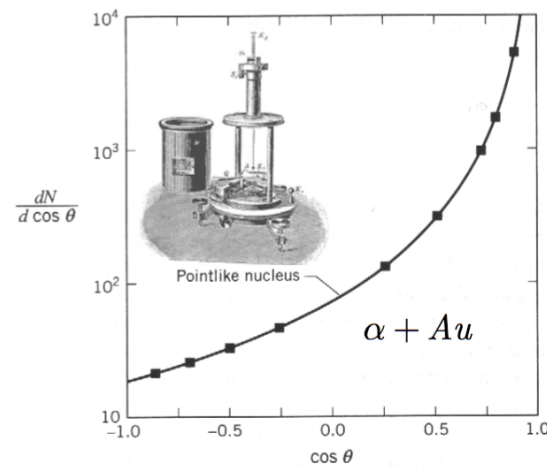
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

# Microscopic structure of matter

Atoms → Nuclei

Nuclei → Nucleons

Nucleons → Quarks



pQCD kinetic plasma



AdS/CFT low viscosity goo

from Thomas Schafer

sQGP liquid  $\leftrightarrow$  quasiparticles (?)

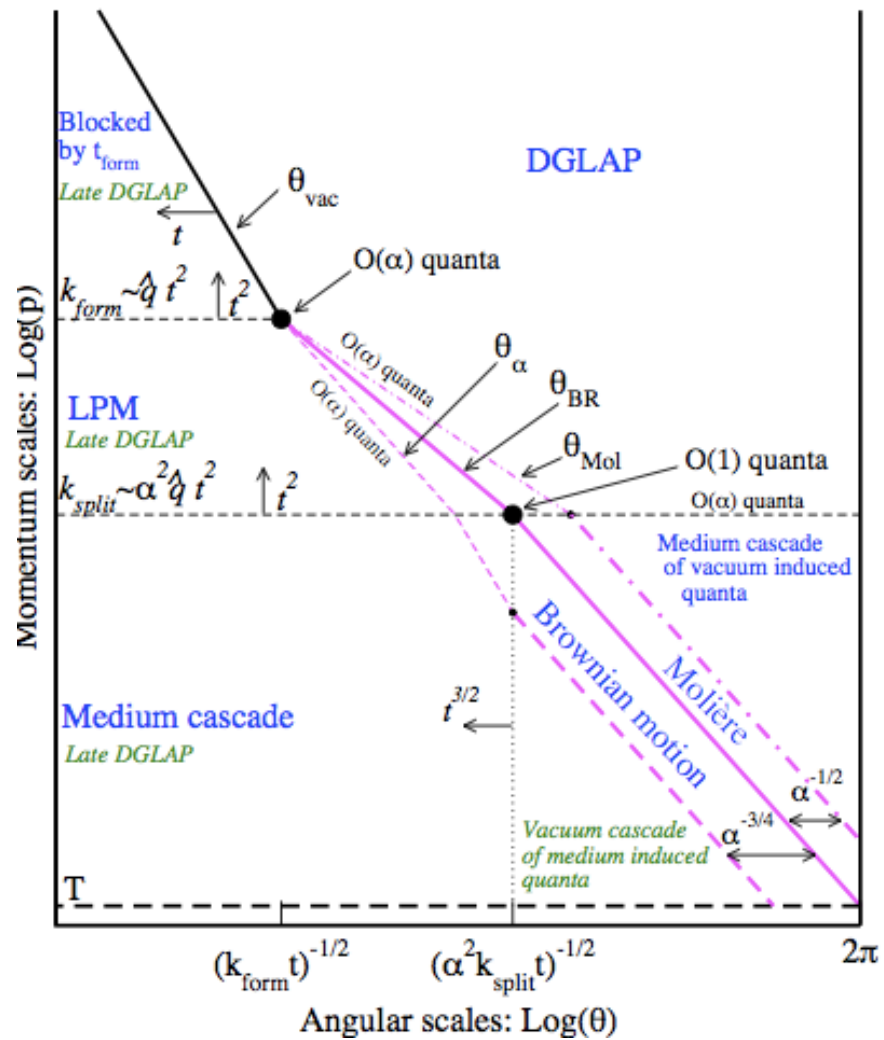
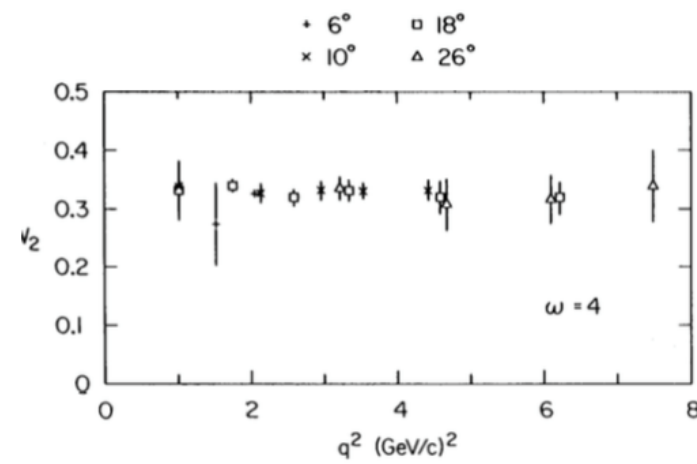
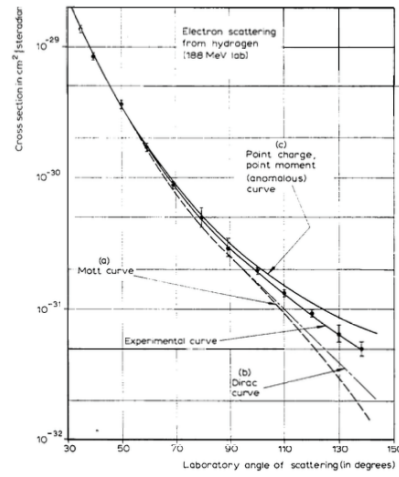
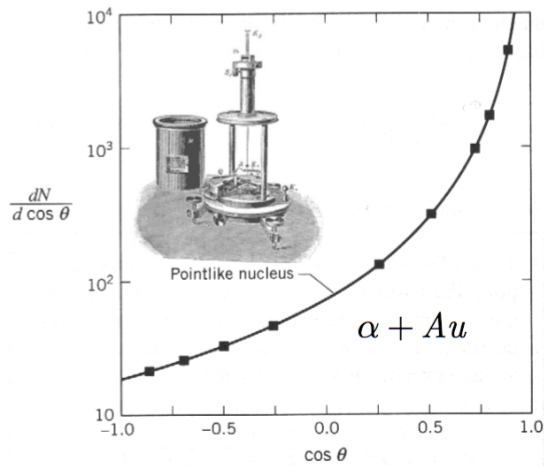


# Microscopic structure of matter

# Atoms→Nuclei

Nuclei  $\rightarrow$  Nucleons

# Nucleons→Quarks



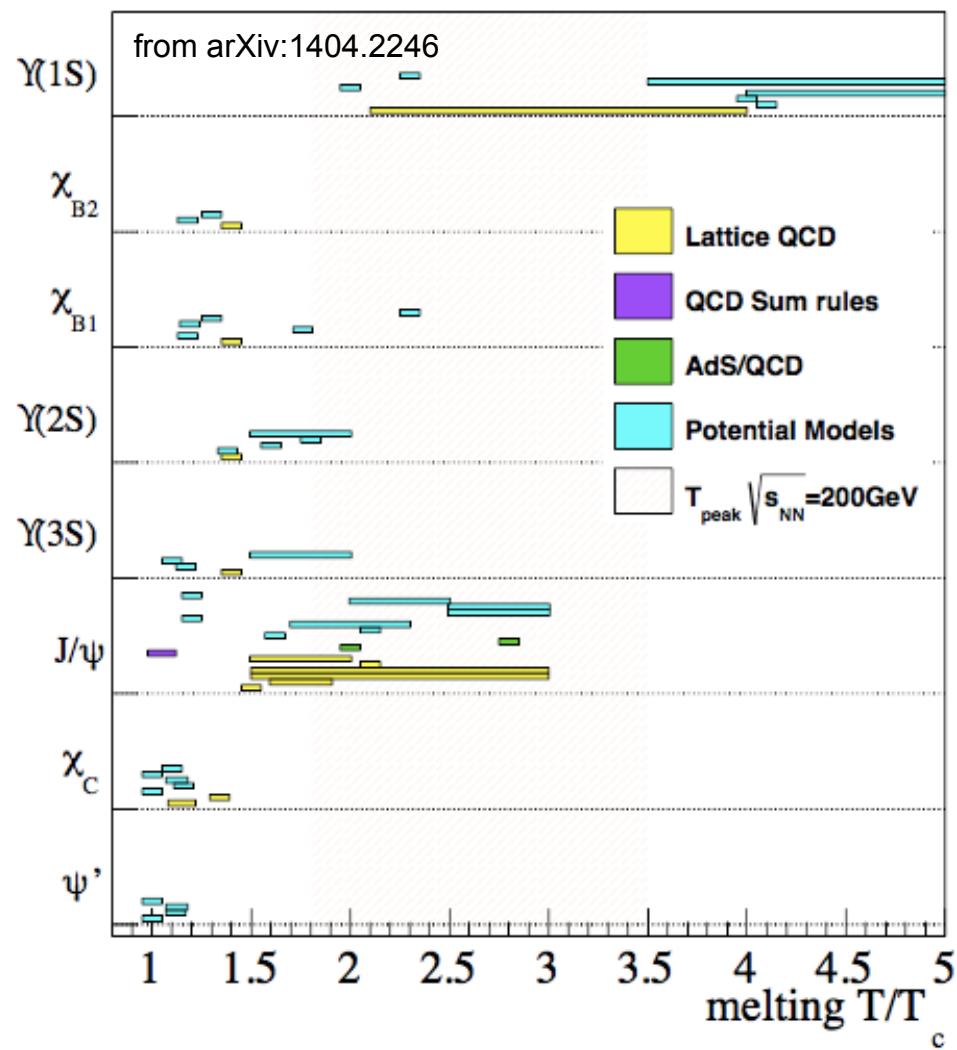
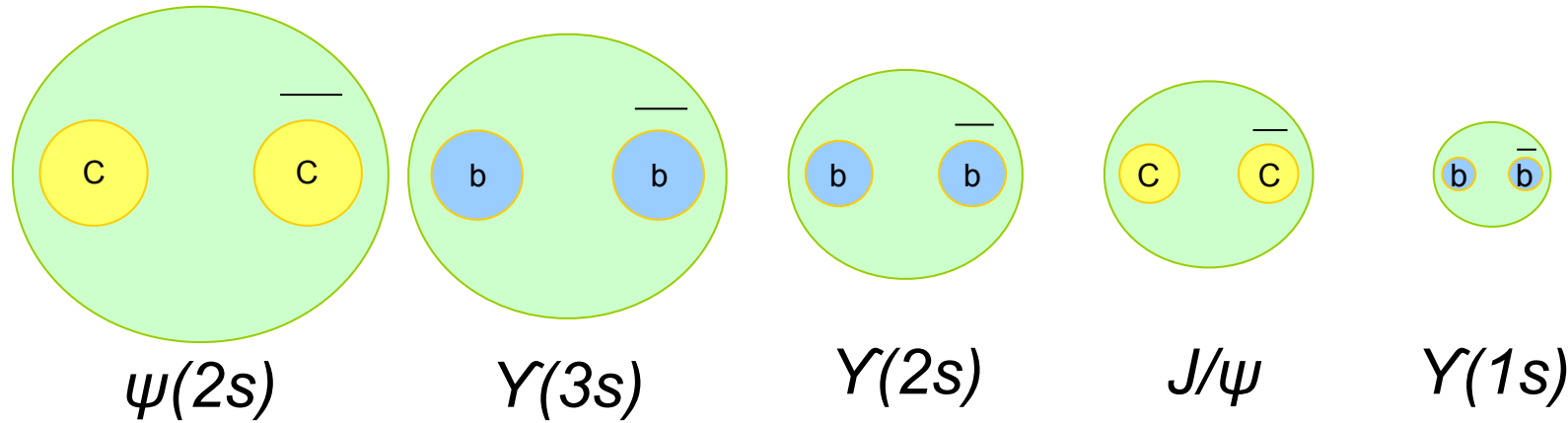
Use multi-scale probes such as jets and  
upsilons to probe QGP at intermediate scales

Unavoidable complexity due to strongly interacting nature of probes

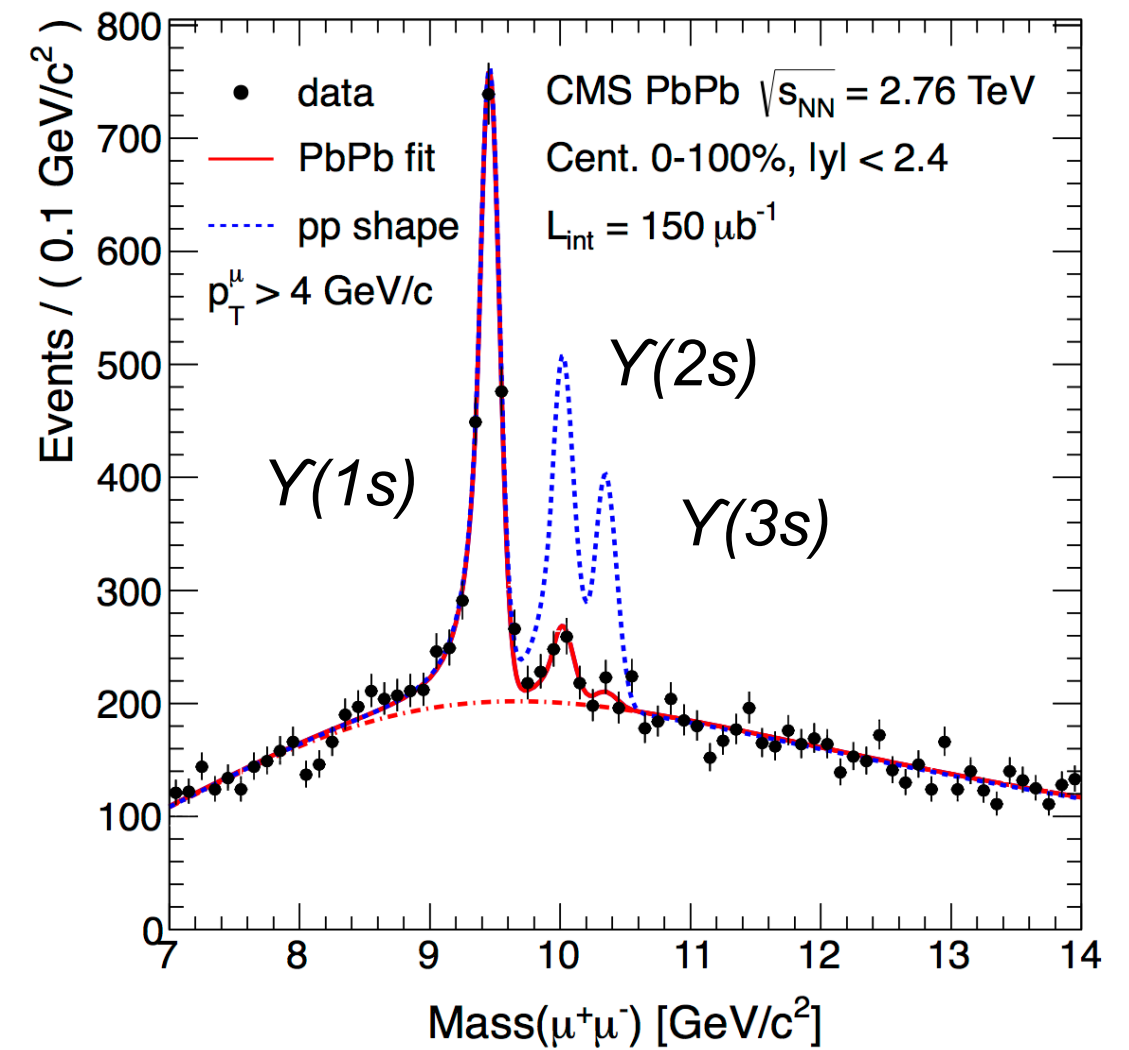


# Multiscale Probes of QGP: Quarkonia

from Yen-Jie Lee



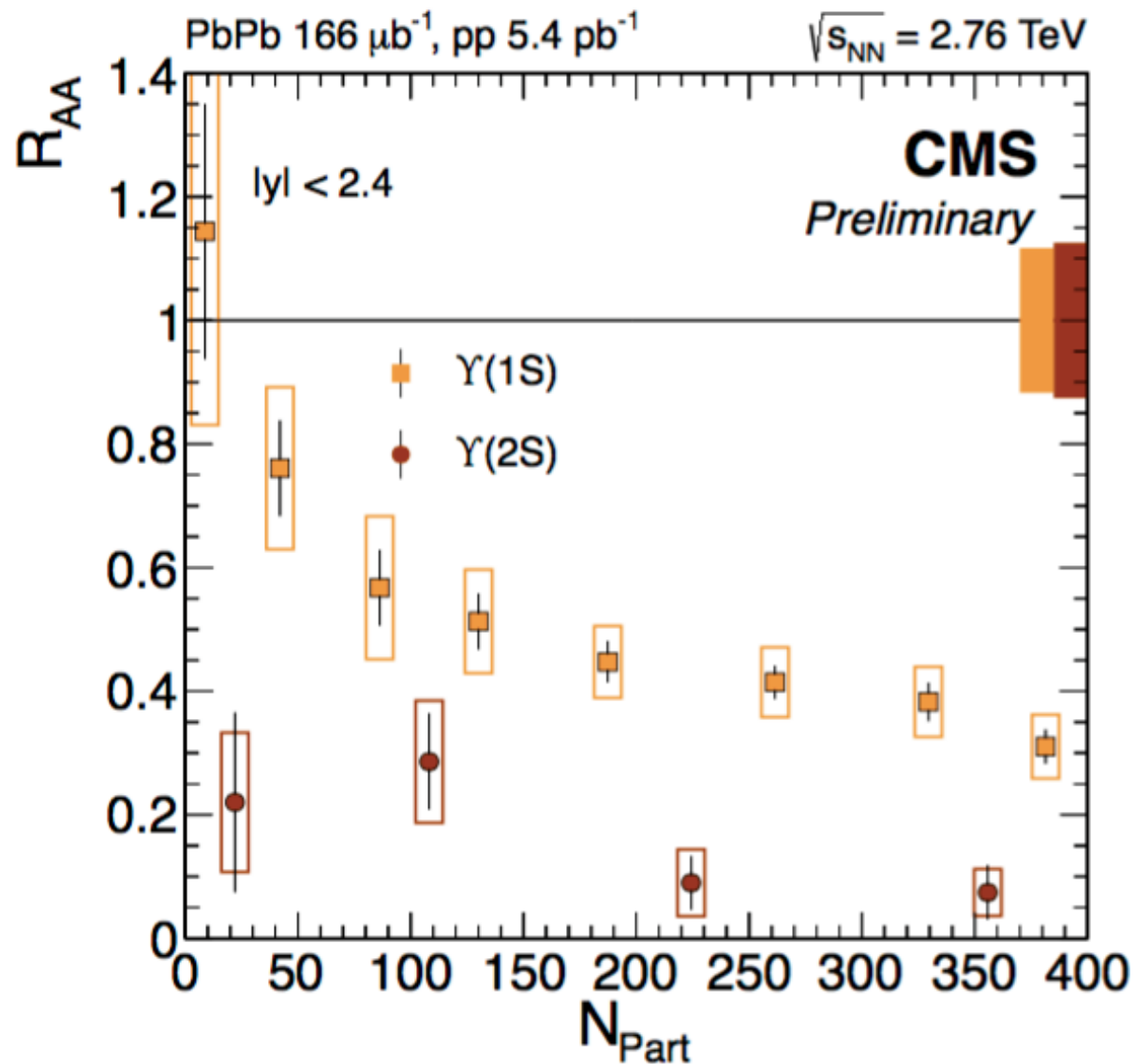
QGP temperature associated  
with characteristic scale (screening length)



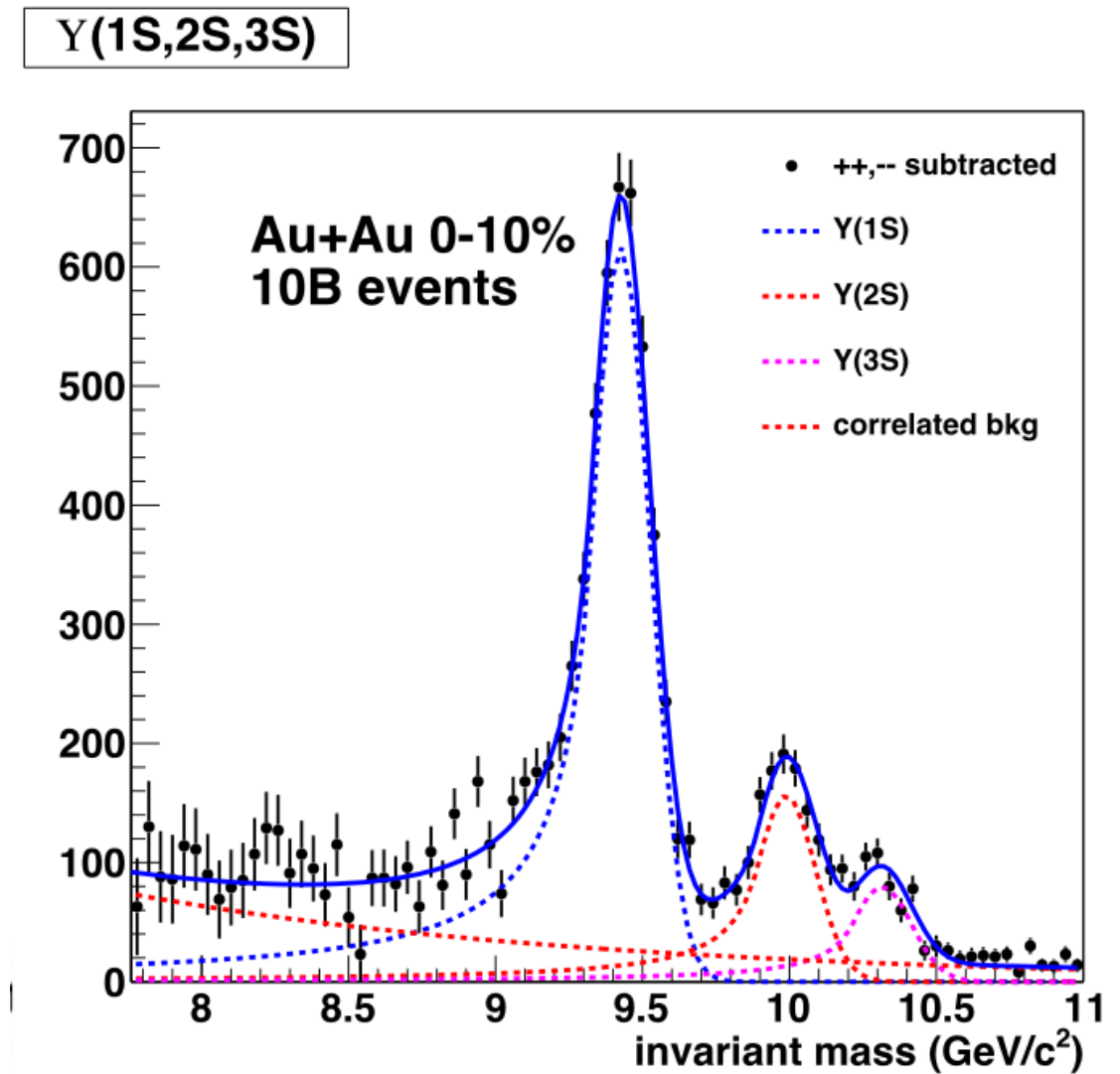
Match of characteristic scale  
of probe and medium



# Nature of probes drives detector requirements



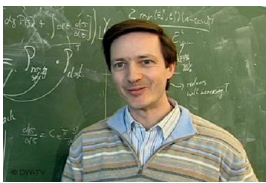
Rapid disappearance of  $\Upsilon(2\text{s})$ ,  $\Upsilon(3\text{s})$  in peripheral events is puzzling →  
Statistics, statistics, statistics...



Count every  $\Upsilon$  delivered →  
high rate, large acceptance

Make every  $\Upsilon$  count →  
excellent momentum resolution

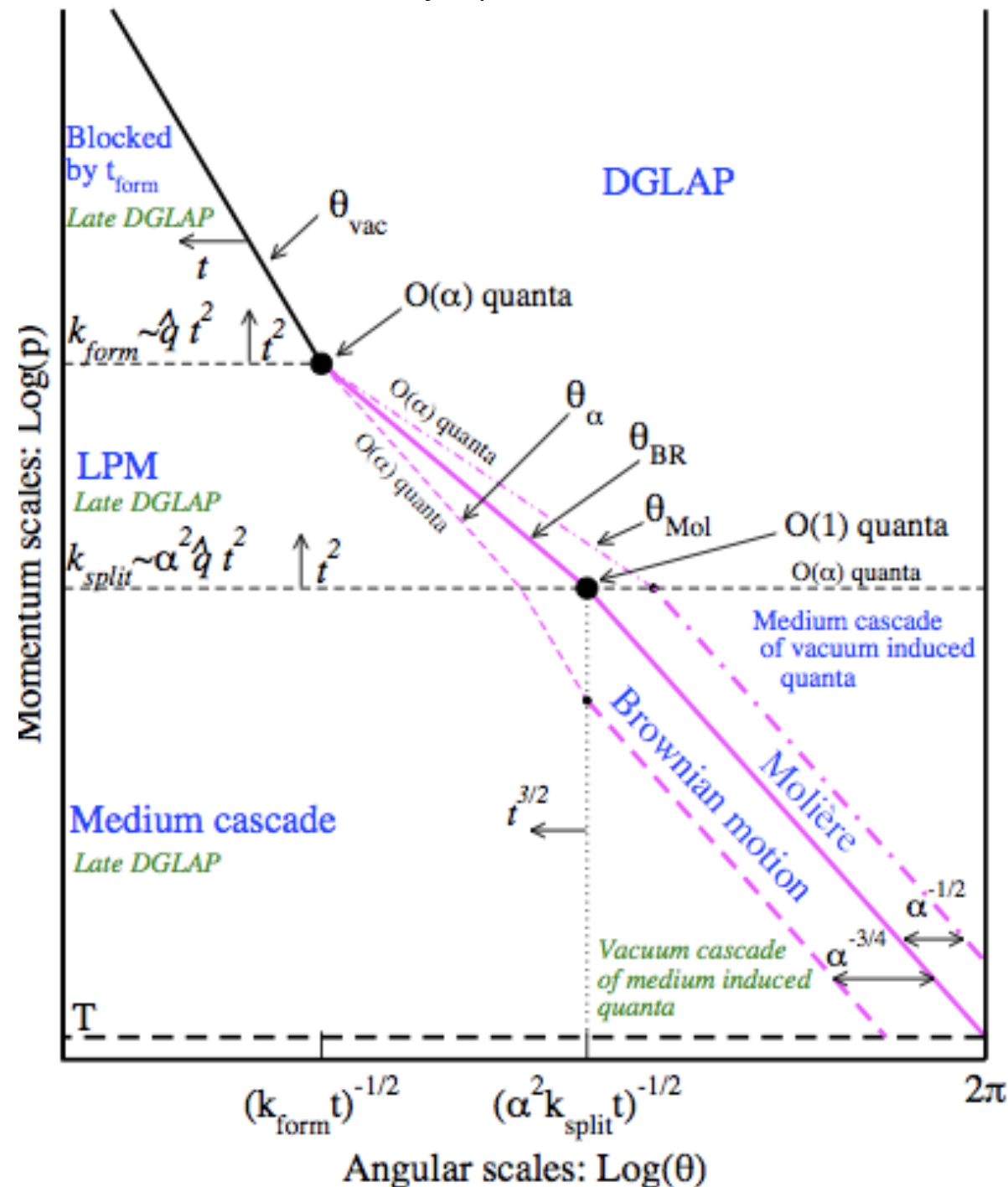




Kurkela,  
Wiedemann,  
arXiv:1407.0293

# Multiscale Probes of QGP: Jets

Snapshot of angular and momentum structure  
of intra-jet parton cascade



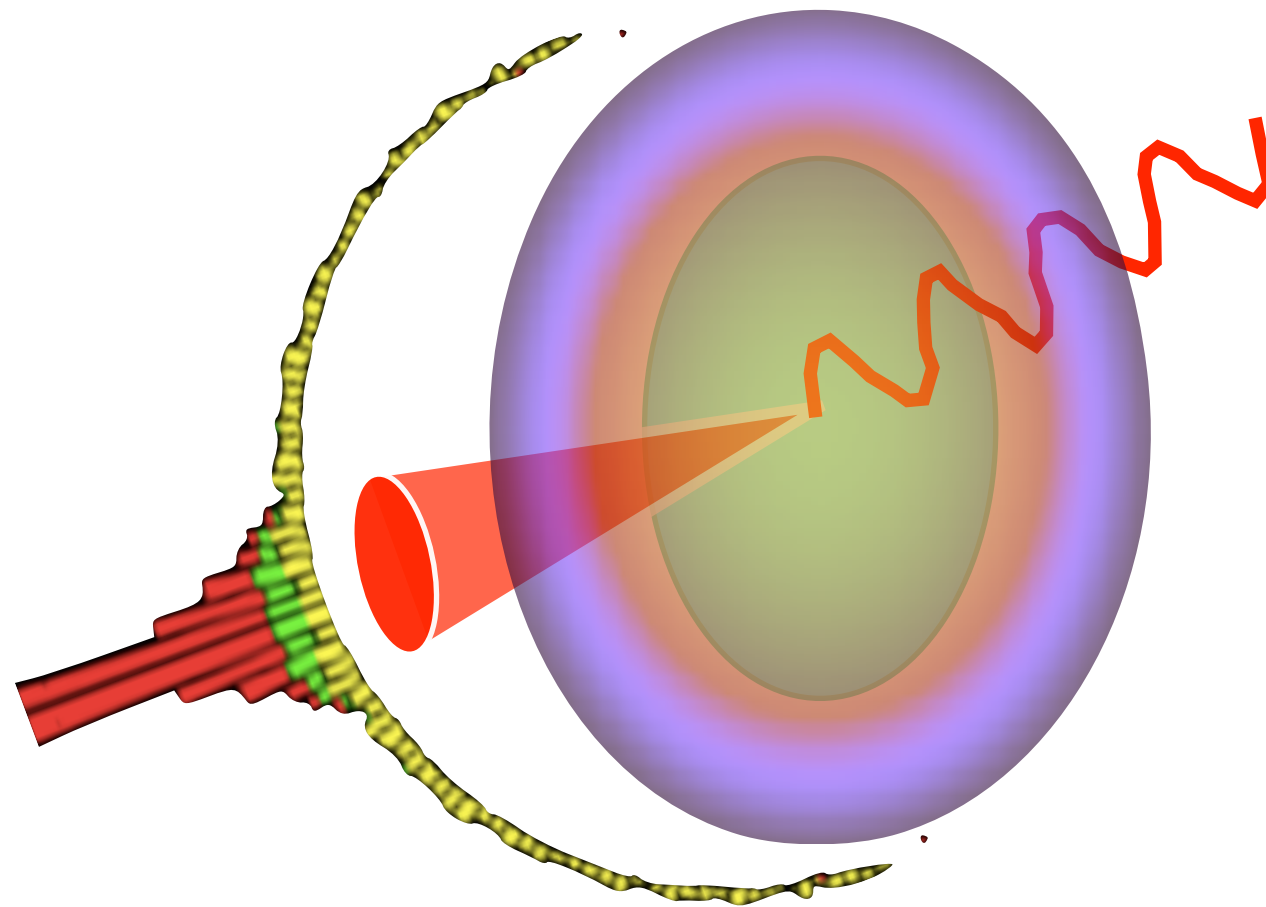
Jet evolves in angular  
and momentum space

At different scales,  
evolution is dominated by  
different mechanisms:

- vacuum evolution
- (jet-constituent)-  
medium scattering
- in-medium cascade



# Nature of probes drives detector requirements



Use away-side and near-side tags to control initial hard system:

- Parton flavor and mass
- Initial momentum
- Pathlength
- In-medium evolution
- Initial and final state radiation

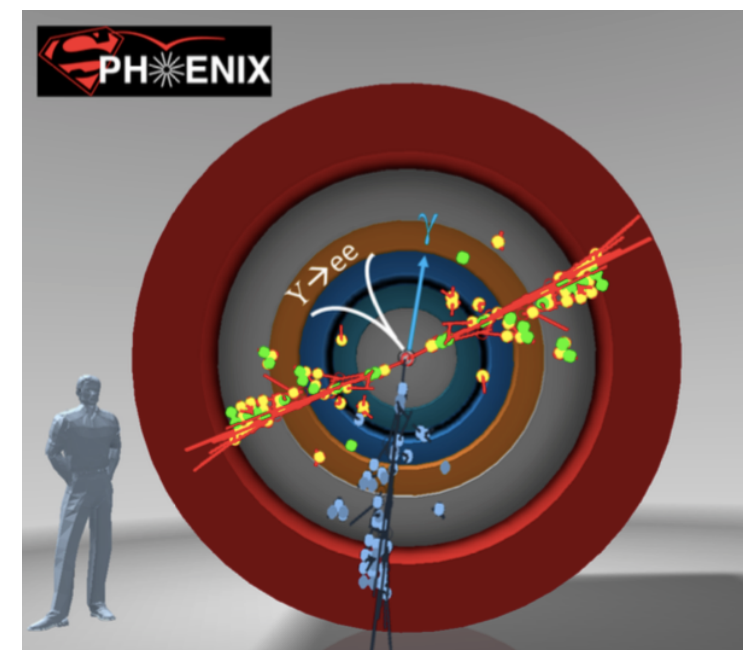
Fully characterize energy flow near the jet, both “in-cone” and “out-of-cone”

## TOMOGRAPHY

: a method of producing a three-dimensional image of the internal structures of a solid object by the observation and recording of the differences in the effects on the passage of waves of energy impinging on those structures

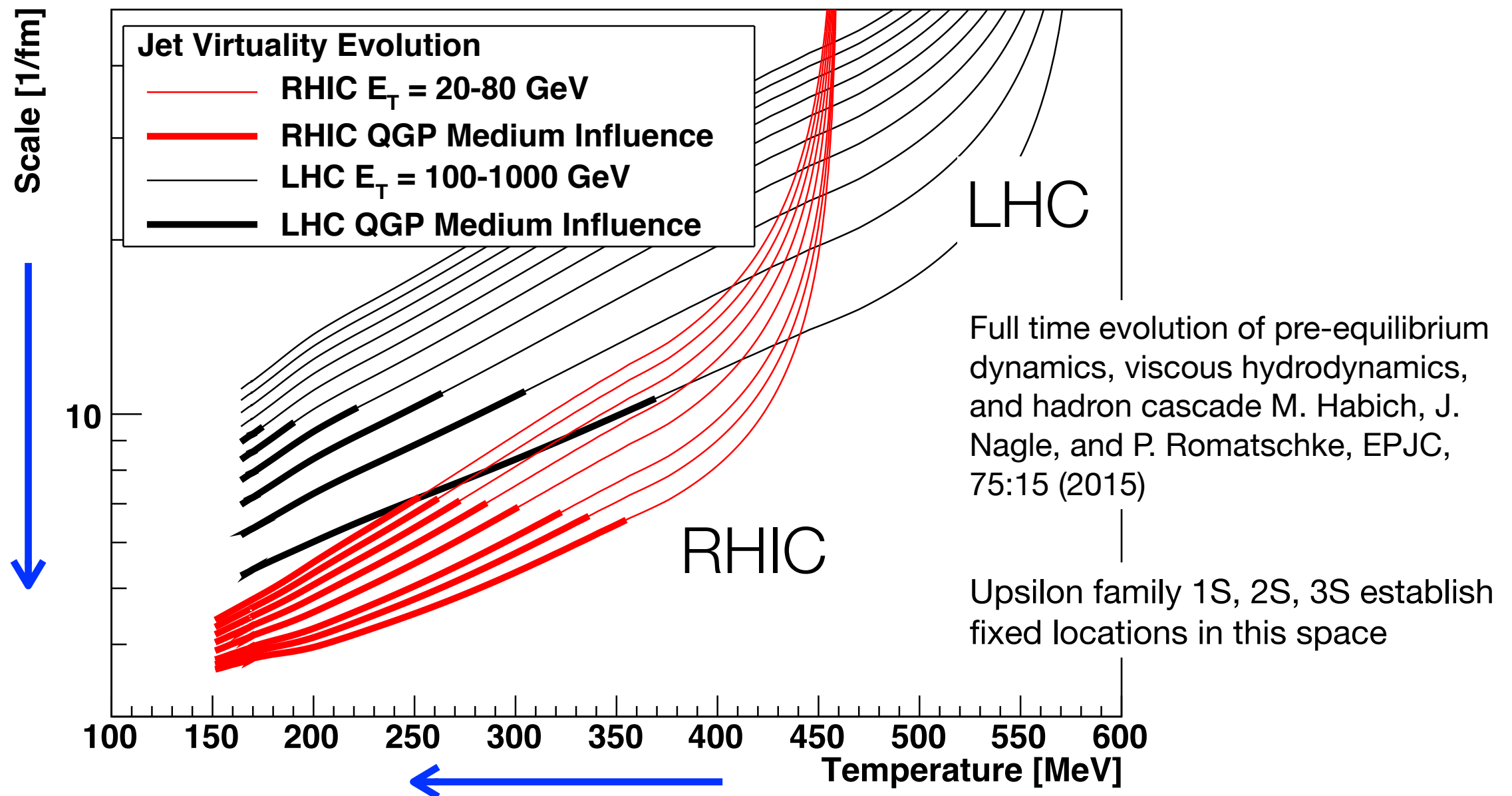


Physics goal	Detector requirement
High statistics for rare probes	Accept/sample full delivered luminosity Full azimuthal and large rapidity acceptance
Precision Upsilon spectroscopy	Hadron rejection $> 99\%$ with good $e^{+/-}$ acceptance Mass resolution $1\%$ @ $m_Y$
High jet efficiency and resolution	Full hadron and EM calorimetry Tracking from low to high $p_T$
Control over parton mass	Precision vertexing for heavy flavor ID
Control over initial parton $p_T$	Large acceptance, high resolution photon ID
Full characterization of jet final state	High efficiency tracking for $0.2 < p_T < 40\text{GeV}$



# RHIC vs LHC complementarity

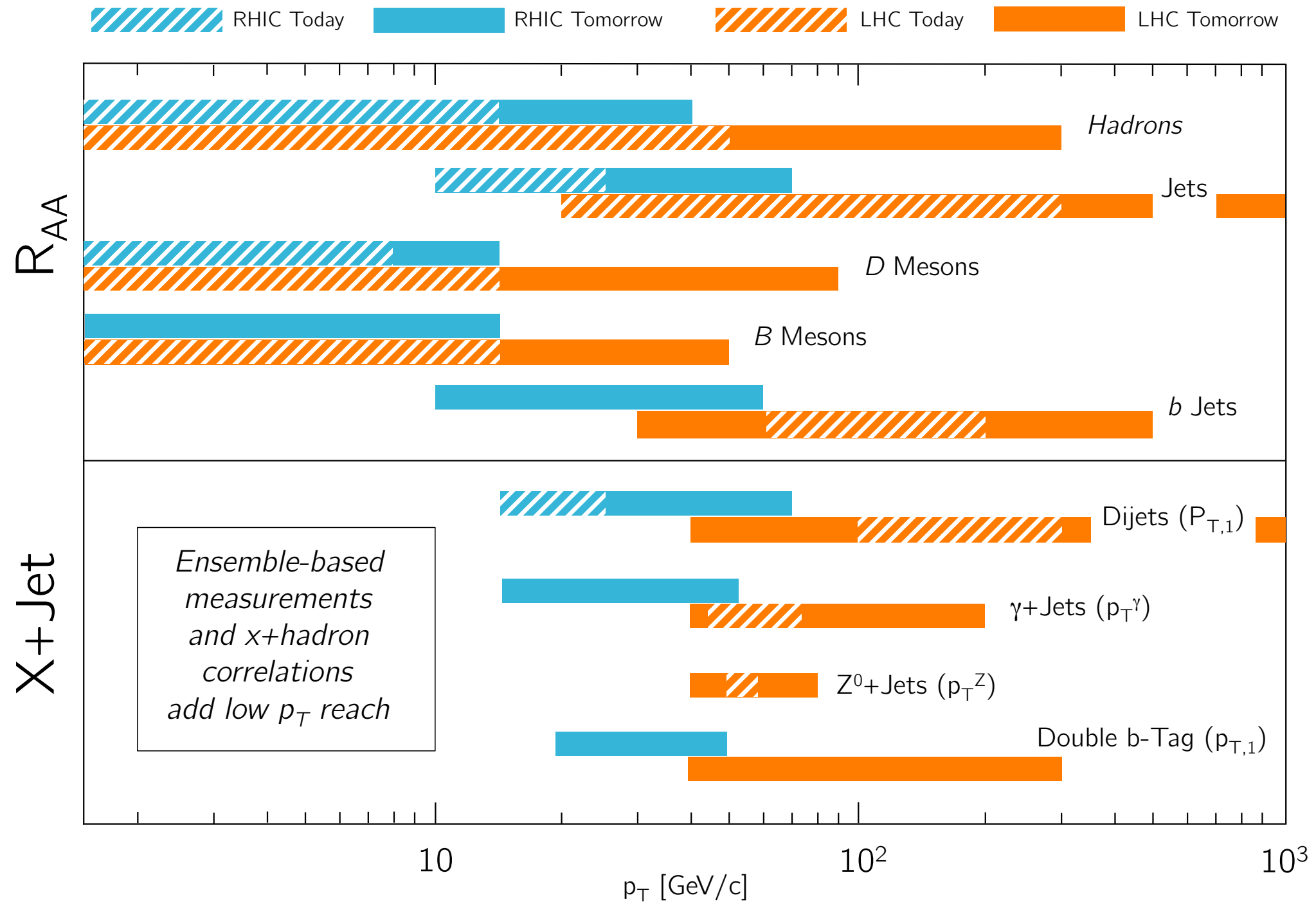
Initial hard scattered parton virtuality in units of 1/fm as a function of the local temperature of the QGP medium



Vacuum virtuality evolution initially, with medium influence becoming significant as virtuality of parton shower and medium become comparable

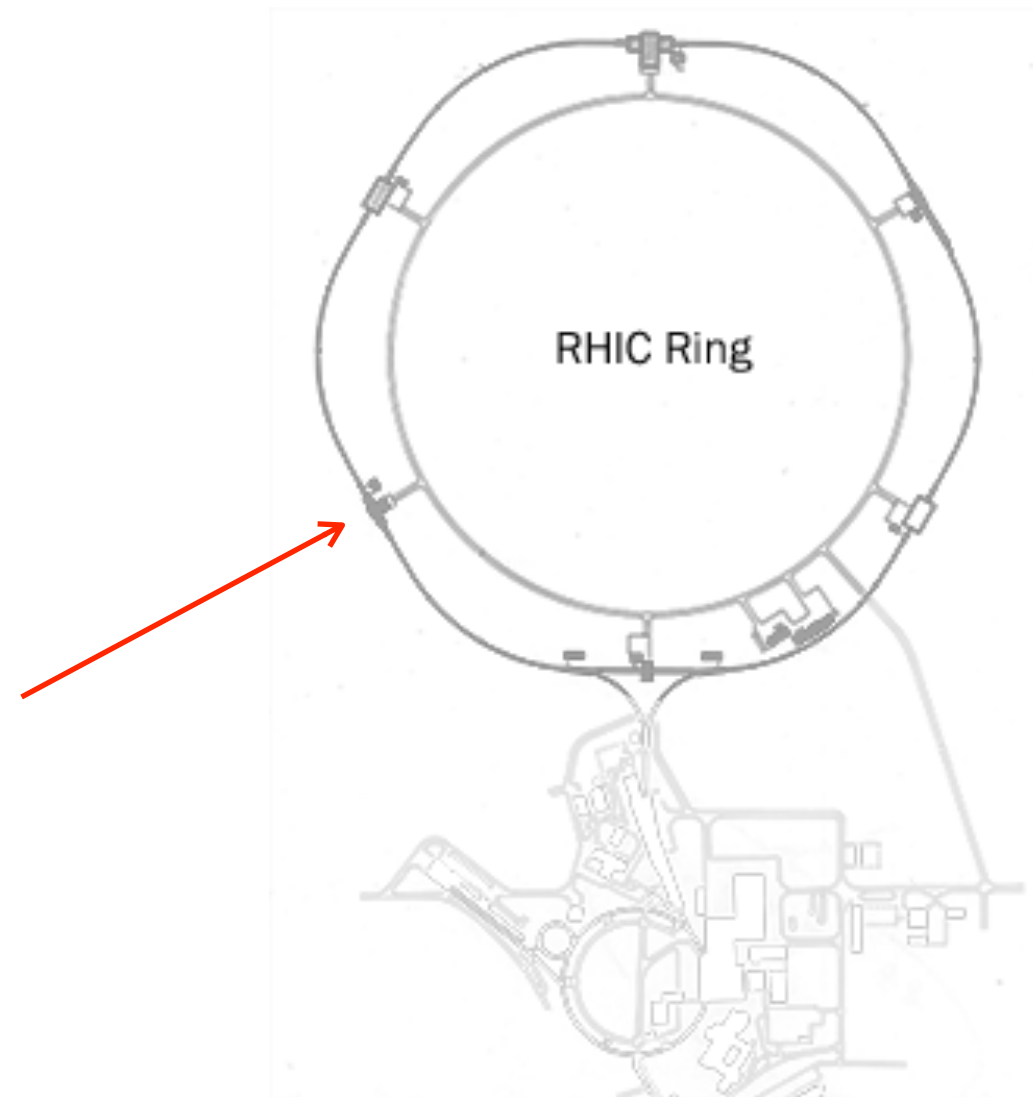
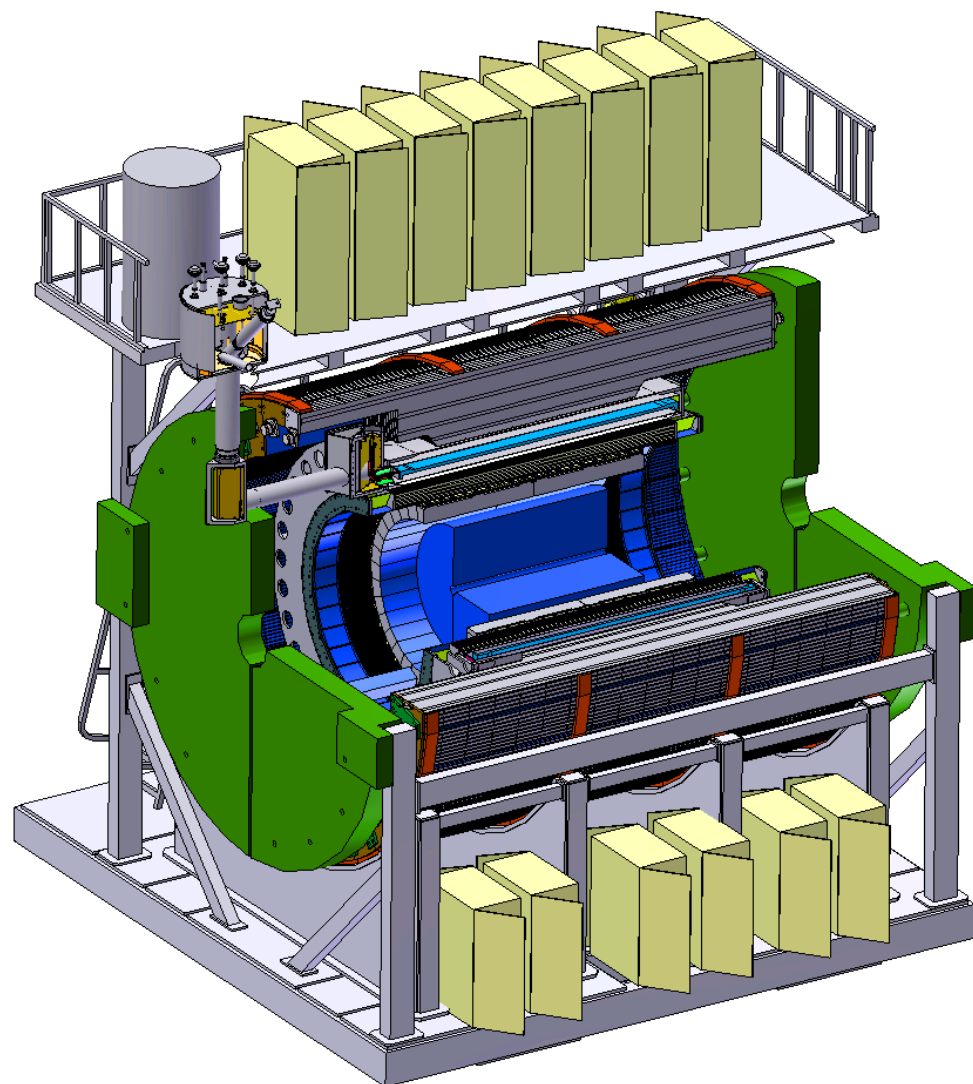


# RHIC/LHC measurements in 2020s



# Building a precision instrument

**sPHENIX:** A high-rate capable detector at RHIC IP8, built around the former BaBar 1.5 T superconducting solenoid, with full electromagnetic and hadronic calorimetry and precision tracking and vertexing, with a core physics program focused on light and heavy-flavor jets, direct photons, Upsilon's and their correlations in p+p, p+A, and A+A to study the underlying dynamics of the QGP – physics delivered by 22 weeks of Au+Au, 10 weeks each of p+p and p+A (@ 200 GeV).





# Summer 2015

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## A Large-Acceptance Jet and Upsilon Detector for RHIC

**General Workshop Registration** (Deadline: June 12, 2015 12:00 AM)

Please note, this workshop **is open** to the public.

[Begin Workshop Registration](#)

### Workshop Announcement

In April 2015, the Office of Nuclear Physics in the Department of Energy conducted a review of the science program enabled by a new detector, sPHENIX, that focuses on large acceptance, ultra-high rate measurements of fully reconstructed jets and high resolution spectroscopy of Upsilon states at RHIC. The outcome of that review was very positive and, while there are important elements of the DOE review process that remain to be completed

#### Workshop Date

June 16, 2015

#### Workshop Location

Brookhaven National Laboratory  
Upton, NY 11973 USA

Physics Department (Bldg 510)  
Large Seminar Room

#### Directions and Maps

[To Event](#) | [To BNL](#)

#### Workshop Coordinator

John Harris as acting IB chair, institutions were asked to indicate their potential interest in the collaboration, leading to a first collaboration meeting at Rutgers in December 2015



# Inaugural sPHENIX collaboration meeting

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Rosi Reed (Lehigh)

Sevil Salur (Rutgers)

Hosts



# Institutions by the time of the Rutgers meeting

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**57 institutions signed up:** Abilene Christian, Augustana College, Banaras Hindu University (India), Baruch College, CUNY, BNL and BNL (PHENIX), UC-Davis, UCLA, UCR, Chonbuk National University (South Korea), Colorado, Columbia, Joint Czech Group (Charles University): Prague Czech Technical University, Prague Institute of Physics, Czech Academy of Sciences – Prague; University of Debrecen, Florida State, Georgia State, Howard University, Houston, sPHENIX (Hungary), Illinois – U.C., Institute of Nuclear Research, Russian Academy of Sciences, Moscow, Iowa State, University of Jammu (India), JAEA (Japan Atomic Energy Agency), Korea University, National Research Centre “Kurchatov Institute”, Lehigh, LLNL, LANL, Maryland, MIT, Michigan, National Research Nuclear University (Moscow Engineering Physics Institute), Muhlenberg College, Nara Women’s University (Japan), New Mexico State, University of New Mexico, ORNL, Ohio University, Institut de Physique Nucléaire d’Orsay, Petersburg Nuclear Physics Institute (National Research Centre “Kurchatev Institute”), IHEP (Protvino), RIKEN/RBRC, Rikkyo University, Rutgers, Stony Brook, Saint-Petersburg Polytechnic University, Tennessee - Knoxville, Texas - Austin, Tokyo Institute of Technology (Tokyo Tech, TITech), University of Tokyo (Center for Nuclear Study), Institute of Physics - University of Tsukuba, Universidad Técnica Federico Santa María - Valparaíso (Chile), Vanderbilt, Wayne State, Weizmann Institute, Yale, Yonsei University (Korea).

# Structure of the scientific collaboration

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- Co-spokespersons (Roland, Morrison)
- Institutional Board (58 institutions)
- Executive Council – elections, appointments complete by late April
- Topical groups – focus on specific observables to drive simulations
  - Jet structure (Dennis Perepelitsa (BNL), Rosi Reed (Lehigh))
  - Heavy-flavor tagged jets (Jin Huang (BNL), Mike McCumber (LANL))
  - Upsilon spectroscopy (Tony Frawley (Florida), Marzia Rosati (Iowa))
  - Cold QCD (under construction)





# Second sPHENIX collaboration meeting May 2016

BNL Intranet Home Page | Brookh... x

← → ↻ <https://intranet.bnl.gov> 🔍 ☆ 🛑 👤 📺 ⋮

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 *Brookhaven Today*



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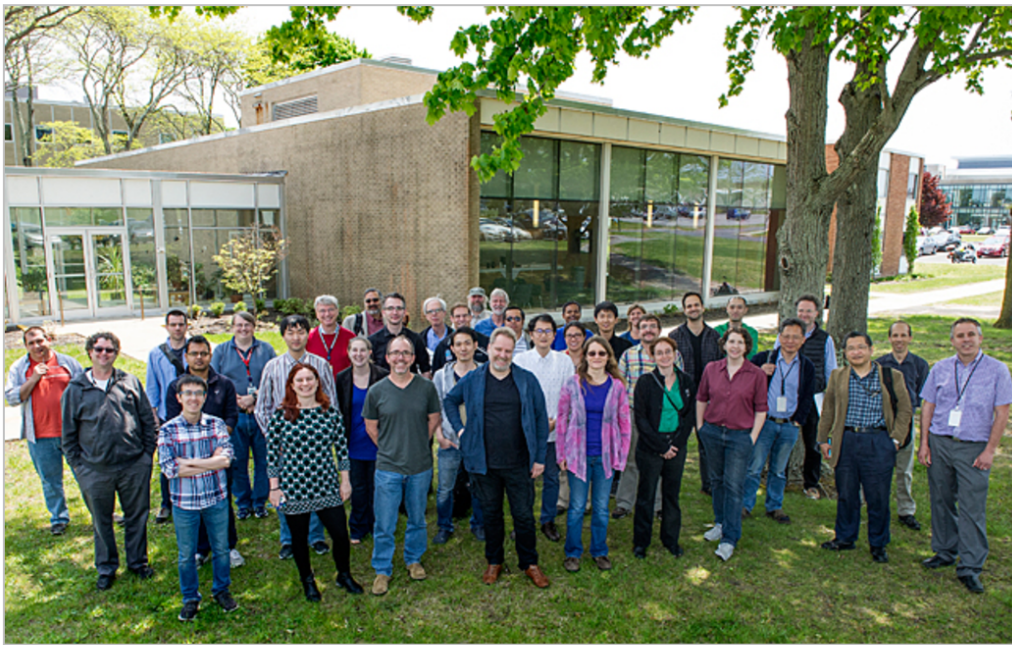
BNL Site Access

Maps & Directions

Guest, User, Visitor Center

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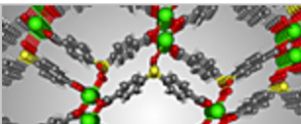


Main Gate Access Forms



**Introducing...sPHENIX!**  
A new collaboration takes aim at understanding how the ultra-hot, ultra-dense plasma that formed our early universe gets its intriguing properties. [More...](#)

Other News

Archives



Safety Resources

FY16 Stats   DART: 9   DOE Recordable: 20

Resources   Report Concern

Announcements

♥ [Two-day Blood Drive Today, 6/15, & Thursday, 6/16](#)

❗ [Safety Day is Friday, 6/17, 10:30 a.m.-1:30 p.m., in Berkner](#)

❗ [Membership Promotions for Costco Wholesale Club in Berkner Thursday, 6/16](#)

✕ [Automated Teller Machine in Berkner \(Bldg. 488\) Out of Service 6/13-7/9](#)

❗ [Sign Up for Free Biometric Wellness Screenings on Safety Day](#)

Newsclips

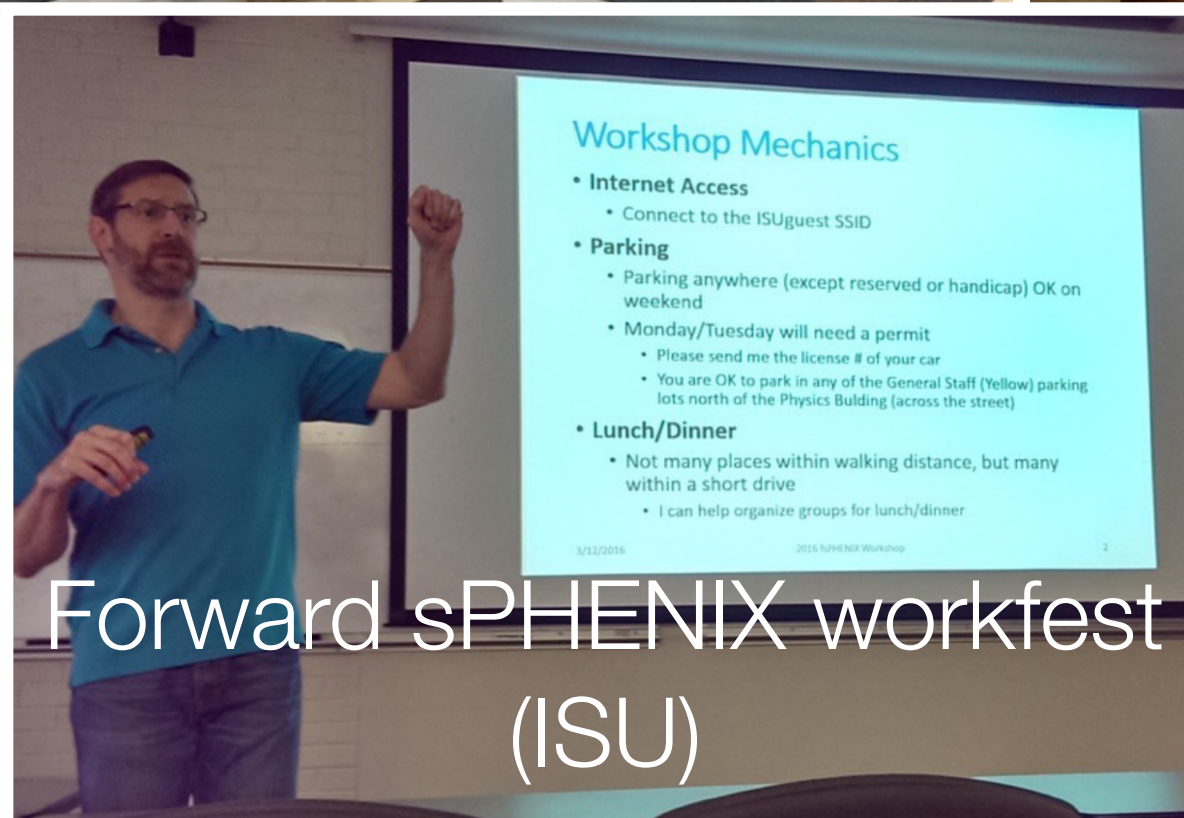
[BNL's Cialella a 'consensus builder' in environmental science](#)

- Village Beacon Record, June 7

17



# Focused “workfests” and other events



- Continues practice that was very productive in developing sPHENIX proposals
- Invite outside experts when appropriate – e.g., discussion with ALICE & STAR experts on space charge distortion in TPC
- Upcoming plans: two-day EMCal workfest in August, two-day test beam paper writing workshop, discussion with ALICE to gauge needs of sPHENIX TPC readout

# Outlook

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- sPHENIX scientific collaboration in full swing – organizing efforts around key science questions to guide work towards 2022 start of physics
- Collaboration is committed to building a world-class experiment with the capabilities needed to deliver the full suite of sPHENIX physics – the scientific questions remain extremely relevant